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VOLUME AND SHARE OF JUVENILE, MATURING AND MATURE WOOD IN STEMS OF NORWAY SPRUCE (*PICEA ABIES* [L.] KARST) GROWN IN MIXED MOUNTAIN FOREST SITES

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Abstract. The article shows relationships occurring between the age of a tree, a social class of tree position in the stand, and the volume and share of juvenile, maturing and mature wood. The object of the study were Norway spruce stands representing age classes II (from 21 to 40 years old), III (41-60 years old) and IV (61-80 years old), grown in mountain forest sites. The zones of juvenile, maturing and mature wood were determined on the basis of the proportion of late wood to early wood share in annual growth ring. Wood made inside leafy branches and within the influence of assimilation apparatus shows different structure and quality if compared with wood made of long way from the assimilation apparatus. That is why we mark juvenile and mature wood. In general juvenile wood is inseparably connection with a strong influence of assimilation apparatus, i.e. with branches of the tree. Juvenile wood is found in every tree and from the point of view of its practical application it is a disadvantageous element, limiting the possible utilization of the wood material.

Key words: juvenile wood, maturing (transient) wood, mature wood, Norway spruce

INTRODUCTION

The wood tissue, forming under a strong influence of leaved branches and in the parts located within the crown, exhibits a different structure than wood forming away from the physiologically active crown [Pazdrowski 2004, Kučera 1994].

Juvenile wood is formed by young cambium within the living, active crown and formed in the shape of a cylinder surrounding the pith over its entire length. Fast tree growth during the first several years causes an increase in the diameter of the juvenile center of the stem [Clark et al. 2005]. The period of its formation in the stem depends on how low the crown of the tree descends [Hejnowicz 2002].

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Numerous studies indicate the effect of the living crown on the quality and amount of produced wood in stems of coniferous trees [Larson 1962, Fabris 2000, Gartner et al. 2002, Pazdrowski and Jakubowski 2000].

Below the crown, where the effect of plant regulators is smaller, mature wood is formed, characterized by lower share of early wood, narrower tracheids and thicker cell walls [Larson 1962, 1973, Bao et al. 2001].

Wood coming from the juvenile zone exhibits several characteristics, which are disadvantageous from the point of view of the quality of produced timber, i.e. a low share of late wood, low density, low cellulose content, a large cellulose fibrils inclination angle, short anatomical elements, considerable shrinkage and swelling, as well as poor stability. Juvenile wood is characterized by low mechanical properties; for this reason wood coming from fast-growing young trees is not recommended for construction purposes [Senft 1985, Kretschmann 1998].

From the point of view of knowledge of wood tissue forming process it is important to understand juvenile wood forming process, and influence of wide mined forest husbandry on its share in tree stems.

The aim of this study was to determine the share of juvenile, maturing and mature wood in stems of spruces representing the main stand according to the Kraft classification (I class – predominant, II class – dominant, and III class – codominant trees). Stands from age classes II (from 21 to 40 years old), III (41-60), and IV (61-80) from mixed mountain forest sites were analysed in this study.

In the study it is assumed, that during the tree stand development in each tree from main stand (in according to Kraft classification) differences succeed in the proportion of quantity of each type of wood tissue.

MATERIAL AND METHODOLOGY

Investigations were conducted on stands in the Szklarska Poręba Forest District with at least 50% share of spruce. Selected stands represented age classes II, III and IV in mixed mountain forest sites. The area covered by these stands made it possible to select 1 hectare of sample plots. Next, breast height diameters of all trees were measured. Measurements were recorded on field record charts using the decimal system in 2-cm diameter classes. Tree height was measured in proportion to the number of trees in individual diameter classes. Next, using data from field record charts the breast height diameters of three sample trees were calculated using the 1st variant of the Urich method [Grochowski 1973]. The sample tree of the smallest diameter was III Kraft's class and the biggest diameter tree was I Kraft's class.

In the second stage of field investigations sample trees were selected. On the stem of each sample tree the northern direction was marked. Next trees were felled, debranched and 2 m sections were marked, from their central parts discs were cut, i.e. at 1 m, 3 m, 5 m, 7 m, up to the top. Moreover, discs were collected from the place of felling of sample trees. On the cut discs successive disc numbers were ascribed (no. 0 was given to the disc from the felling place), and the northern direction was marked in each disc.

Laboratory analyses using to calculate width of the zones of early and late wood in spruce stems were performed with an electronic increment meter. Measurements were initiated starting from the pith, taking successive readings of early and late wood with accuracy to 0.01 mm. Measurements were taken in four geographical directions (N – north, S – south, W – west, E – east).

Measured values were recorded using computer software *Przyrostomierz Codima* on a personal computer.

The results were analysed, starting with coping of the previously recorded data to *Microsoft Excel* software.

Next on each disc collected from the stem calculation procedures were initiated:

– widths of early and late wood zones in four geographical directions were calculated
– next mean early and late wood increments in four geographical directions were calculated
– the mean growth ring width was calculated from mean values of early and late wood width
– the early to late wood ratio was calculated, on the basis of its widths (l/e).

On the basis of these values graphs were prepared, which were the basis for the differentiation of the zone of juvenile, maturing and mature wood. Graphs were prepared from cross – sections at the height of 1.3 m (breast height). As juvenile wood was accepted wood with l/e ratio less than 20%, as maturing wood was accepted wood with l/e ratio from more than 20% to 40% and mature wood with more than 40% l/e ratio. Figure 1 shows an example of delimitance between area obtained by each kind of wood.

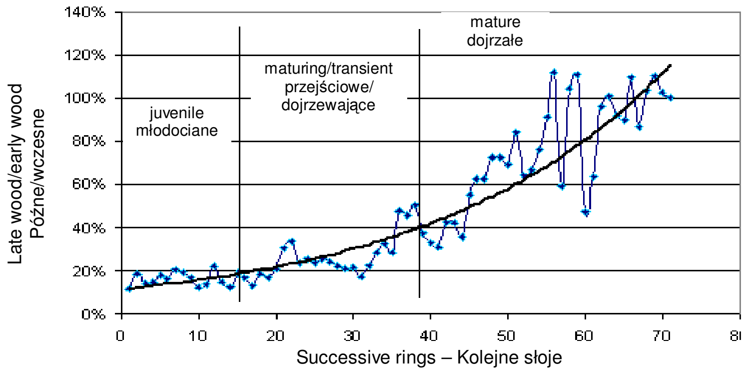

Fig. 1. Delimitance between area obtained by each kind of wood, defined on the basis of ratio of share of late wood to early wood (l/e)) in annual ring, i.e. from dominant tree, representing IV class of age

Rys. 1. Rozgraniczenie poszczególnych rodzajów drewna na podstawie stosunku grubości drewna późnego do wczesnego (p/w) w przyroście rocznym na przykładzie drzewa panującego, reprezentującego IV klasę wieku

Using the previously obtained data the whole trees volumes were calculated as well as volumes of individual zones of juvenile, maturing and mature wood. Huber's formula was used for this purpose. Next statistical characteristics of distinguishing zones of wood (juvenile, maturing, mature) were calculated.

RESULTS

Wood of coniferous species characterized by narrow annual growths, has better strength parameters than trees with wide increments [Kokociński 2004]. Mature wood is characterized by relatively small widths of annual growth and thus a higher share of late wood in annual growth ring. Comparing graphs presenting changes in wood rings width from the pith to the circumference of the tree with graphs of the proportion of the share late wood to early wood in annual growth ring the mirror reflection effect may be observed (Figs. 2-4). This phenomenon results from the growth increment characteristic of coniferous species, because when annual increment of width is increasing, together is increasing the share of thin wall early wood, while width of late wood zone stays unchanged [Krzysik 1970]. Thus an inversely proportional dependence was found between the width of annual growth rings and the ratio of late and early wood share in annual growth rings.

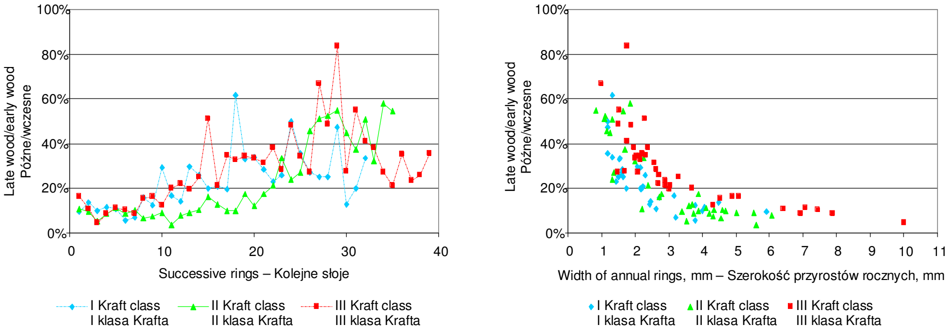

Fig. 2. The ratio of share late to early wood in annual rings (l/e); and dependence between the ratio (l/e) and width of annual rings in selected Kraft's social class – in age class II
Rys. 2. Stosunek udziału drewna późnego do wczesnego w słoju rocznym (p/w) oraz zależność między stosunkiem udziału drewna późnego do wczesnego (p/w) a szerokością przyrostów rocznych na tle wybranych klas Krafta w II klasie wieku

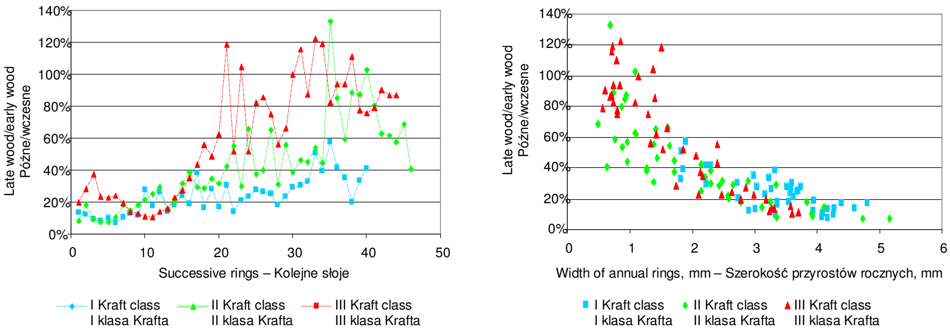

Fig. 3. The ratio of share late to early wood in annual rings (l/e); and dependence between the ratio (l/e) and width of annual rings in selected Kraft's social class – in age class III
Rys. 3. Stosunek udziału drewna późnego do wczesnego w słoju rocznym (p/w) oraz zależność między stosunkiem udziału drewna późnego do wczesnego (p/w) a szerokością przyrostów rocznych na tle wybranych klas Krafta w III klasie wieku

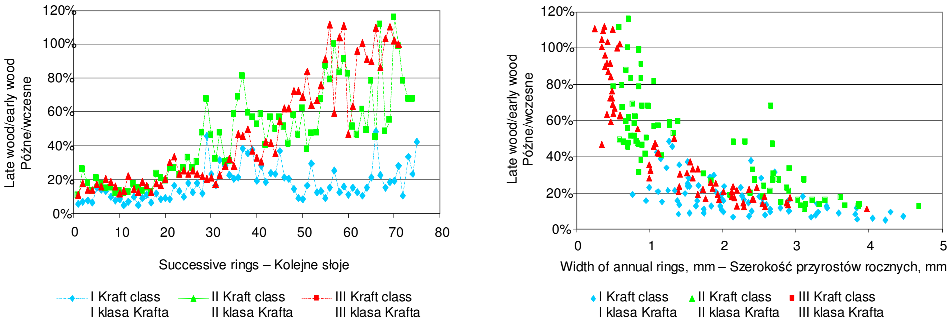

Fig. 4. The ratio of share late to early wood in annual rings (l/e); and dependence between the ratio (l/e) and width of annual rings in selected Kraft's social class – in age class IV
Rys. 4. Stosunek udziału drewna późnego do wczesnego w słoju rocznym (p/w) oraz zależność między stosunkiem udziału drewna późnego do wczesnego (p/w) a szerokością przyrostów rocznych na tle wybranych klas Krafta w IV klasie wieku

The fluctuations of the share of volumes of individual wood types in age classes and Kraft classes are presented in Figs 5, 6 and 7. The mean share of juvenile wood in the trees volume in age class II was 70.6%, in age class III – 70.3%, while in age class IV – 68%. The mean share of maturing wood in the trees volume in age class II was 23.4%, in age class III – 20.4%, and in age class IV it was 19.3%. The mean share of mature wood in age class II amounted 8.2%, in age class III – 9.2%, while in age class IV – 13.8%.

It results from the quoted data that the share of juvenile wood and maturing wood decreases with the age of the tree. An opposite dependence may be observed for mature wood, which share increases with age when analysing the breast height sample of the tree.

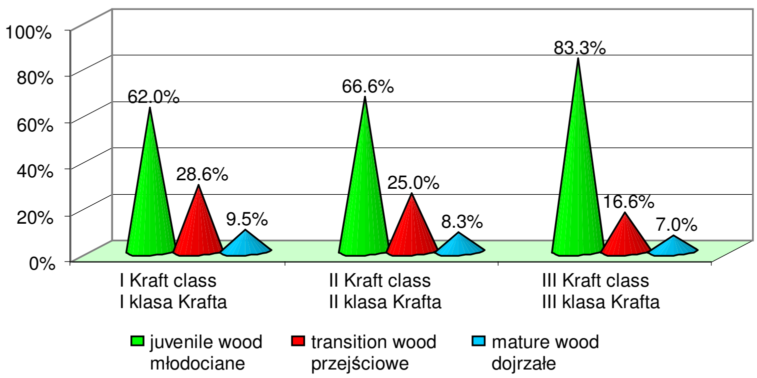

Fig. 5. The share of volumes of individual types of wood beside to volume of full tree – in II age class
Rys. 5. Udział miąższości poszczególnych rodzajów drewna względem miąższości całego drzewa w II klasie wieku

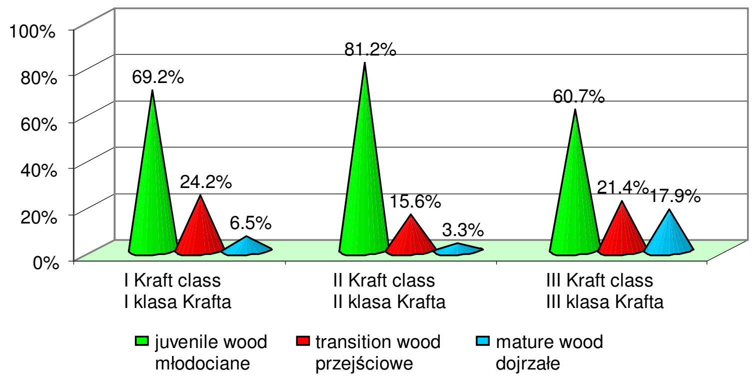

Fig. 6. The share of volumes of individual types of wood beside to volume of full tree – in III age class
Rys. 6. Udział miąższości poszczególnych rodzajów drewna względem miąższości całego drzewa w III klasie wieku

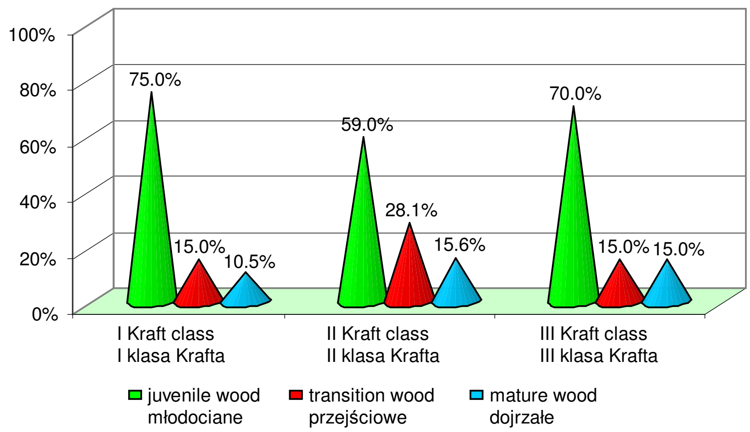

Fig. 7. The share of volumes of individual types of wood beside to volume of full tree – in IV age class
Rys. 7. Udział miąższości poszczególnych rodzajów drewna względem miąższości całego drzewa w IV klasie wieku

When analysing the mean width of the ring inconsiderable differences were observed in individual age classes. A definitely biggest mean width of the ring was shown for trees of age class III. Trees of age class II and IV have shown similar quantity of width of annual thickness increment. The mean width of the ring of mature wood showed the lowest quantities in age class IV (Table 1). It was observed, that in age class IV there was a considerable increase of share of mature wood comparing with younger age classes.

Table 1. Characteristics of widths of annual growth in age classes
Tabela 1. Charakterystyka szerokości przyrostów rocznych w klasach wieku

Age class Klasa wieku	Arithmetic mean of widths of annual rings, mm Średnia arytmetyczna szerokości słojów rocznych, mm			
	juvenile wood drewno młodociane	maturing/transient wood drewno przejściowe/ dojrzewające	mature wood drewno dojrzałe	arithmetic mean średnia arytmetyczna
II	3.49	2.35	1.95	2.59
III	3.77	2.94	2.04	2.91
IV	3.48	2.40	1.56	2.43

DISCUSSION

The primary aim of the study was to determine the share of juvenile, maturing and mature wood volume in stems of Norway spruce grown in mixed mountain forest site.

Earlier studies showed considerable differences in the effect of the forest site type on the share of juvenile wood in tree stems. Jakubowski [2000, 2004] found an effect of the forest site type on the share of juvenile and maturing wood in Scots pine. Different results were presented by Thornqvist [1993], who investigating pine and spruce in Scandinavia – stated that the length of the period, in which juvenile wood is formed depends on the species, and not on the site. The above theory was contradicted by Clark and Saucier [1989], in whose opinion the width of the juvenile wood zone does not depend on the species, but on environmental factors connected with topography and geographical location.

There is no connection with Kraft's class (to which investigated trees were counted), and the share of individual wood types in its stems. Similar conclusions were drawn by Jakubowski [2000] who stated that the social class of tree position in the stand did not have an effect on the share of juvenile, maturing and mature wood in stems of Scots pine.

A slight effect was found of the age of tree on the share of individual wood types in stems. With increasing of the age share of mature wood increased irregularly, and the share of maturing and juvenile wood decreasing. Jakubowski [2004] showed that the differentiation of the share of mature and juvenile wood occurs only in pines of older age classes. In stands of age class II and III the shares were similar and only starting in age class IV it started to differentiate markedly. The quality of macrostructure in practice may thus become important only in stems of at least 60-year old trees.

A marked decrease was also observed in the width of the annual ring progressing with the age of the tree, and also was observed – earlier by many authors showed regularity which is in coniferous wood, that the width of annual ring is inversely proportional to the share of late wood in the ring. Similar observations were reported by Giefing et al. [2005].

However, the species specific character of Norway spruce needs to be mentioned here, manifested in the fact that it uses very effectively the light increment, resulting from the shade tolerance of this species, which may be of considerable importance for the share of individual wood types. A similar role may also be found for the character of tending inventions conducted in the past as well as mixing with other species of forest trees. In the opinion of Giefing et al. [2005] natural regeneration ensures the production of more homogenous timber with better strength properties.

CONCLUSIONS

Investigations made it possible to formulate the following conclusions:

1. There was found no connection with Kraft's class (to which investigated trees were counted) and the share of juvenile, maturing and mature wood.
2. A slight effect of age was found on the share of juvenile, maturing and mature wood. The mean share of juvenile wood in age class II was 70.6%, in class III 70.3 and it was 68% in age class IV. The share of maturing wood in trees of age class II was 23.4%, age class III was 20.4 and in age class IV it was 19.3%. Mature wood constituted 8.2% in age class II, 9.2% in age class III and 13.8% in age class IV.
3. The highest mean width of annual growth width have trees from the age class III. The investigated trees from age classes II and IV were characterized by similar the mean width of annual rings. The mean width of annual ring was stated markedly smaller in the trees of IV class of age.
4. The share of late wood to early wood in annual ring is inversely proportional to the width of the annual ring.
5. It was observed, that in age class IV the wood tissue takes a specific, more mature character, expressed in much higher share of mature wood, than in the younger age classes.

REFERENCES

Bao F.C., Jiang Z.H., Jiang X.M., Lu X.X., Luo X.Q., Zhang S.Y., 2001. Differences in wood properties between juvenile wood and mature wood in 10 species grown in China. Wood Sci. Technol. 35, 363-375.

Clark III A., Saucier J.R., 1989. Influence of initial planting density, geographic location, and species on juvenile wood formation in southern pine. For. Prod. J. 39, 7/8, 42-48.

Clark III A., Daniels R.F., Jordan L., 2005. Juvenile/mature wood transition in Loblolly pine as defined by annual ring specific gravity, proportion of latewood, and microfibril angle. Wood Fiber Sci. 38, 292-299.

Fabris S., 2000. Influence of cambial ageing, initial spacing, stem taper and growth rate on wood quality of three coastal conifers. Univ. British Columbia Vancouver.

Gartner B.L., North E., Johnson, Singleton R., 2002. Effects of live crown on vertical patterns of wood density and growth in Douglas – fir. Can. J. For. Res. 32, 439-447.

Giefing F.G., Pazdrowski W., Spława-Neyman S., Jelonek T., Tomczak A., 2005. Wood radial cyclic heterogenity of Nowary spruce (*Picea abies* (L.) Karst.) derived from ripening stands. EJPAU 8, 4.

Grochowski J., 1973. Dendrometria [Dendrometry]. PWRiL Warszawa [in Polish].

Hejnowicz Z., 2002. Anatomia i histogeneza roślin drzewiastych [Anatomy and histogenesis of woody plants]. PWN Warszawa [in Polish].

Jakubowski M., 2000. Wpływ siedliska pozycji biosocjalnej i wieku drzew na kształtowanie się udziału drewna młodocianego oraz bielastego i twardzielowego w strzałach sosen zwyczajnych (*Pinus sylvestris* L.) [Influence of site, social position and age of trees to shape a share of juvenile wood and sapwood and heartwood in Scots pine (*Pinus sylvestris* L.) stems]. AR Poznań [in Polish; typescript].

Jakubowski M., 2004. Udział bielu, twardzieli, drewna młodocianego i dojrzałego w strzałach sosen zwyczajnych (*Pinus sylvestris* L.) wyrosłych w różnych warunkach siedliskowych [The share of sapwood, heartwood, juvenile and mature wood in stems of Scots pine (*Pinus sylvestris* L.) grown in various forest sites]. Sylwan 8, 16-24 [in Polish].

Kokociński W., 2004. Drewno. Pomiary właściwości fizycznych i mechanicznych [Wood. The measurements of physical and mechanical properties]. PRODRUK Poznań [in Polish].

Kretschmann D.E., 1998. Properties of juvenile wood. Techline. Properties and use of wood, composites, and fiber products. Issued 09/98.

Krzysik F., 1970. Nauka o drewnie [Knowledge of wood]. PWN Warszawa [in Polish].

Kučera B., 1994. A hypothesis relating current annual height increment to juvenile wood formation in Norway spruce. Wood Fibre Sci. 26, 1, 152-167.

Larson P.R., 1962. A biological approach to wood quality. TAPPI 45, 443-448.

Larson P.R., 1973. The physiological basis for wood specific gravity in conifers. In: IUFRO Division 5 Meeting, Brisbane, Australia. Vol. 2, 672-680.

Pazdrowski W., 2004. The proportion and some selected physical and mechanical properties of juvenile, maturing and adult wood of Black pine and Scots pine. EJPAU 7, 1, 1-8.

Pazdrowski W., Jakubowski M., 2000. Objętość korony a udział drewna młodocianego w strzale sosny zwyczajnej (*Pinus sylvestris* L.) [Volume of crown versus share of juvenile wood in Scots pine (*Pinus sylvestris* L.) stems]. In: Materiał III Konferencji Leśnej. IBL, 268-273 [in Polish].

Senft J.F., 1985. Practical significance of juvenile wood for the user. In: Proc. 18th IUFRO World Congress. Div. 5. Ljubljana 7-21 Sept.

Thornqvist T., 1993. Juvenile wood in coniferous trees. Report D13: 1993. Stockholm, Byggforskningsradet.

MIĄŻSZOŚĆ I UDZIAŁ DREWNA MŁODOCIANEGO, DOJRZEWAJĄCEGO ORAZ DOJRZAŁEGO W STRZAŁACH ŚWIERKA POSPOLITEGO (*PICEA ABIES* [L.] KARST) WYROSŁEGO W WARUNKACH SIEDLISKA LASU MIESZANEGO GÓRSKIEGO (LMG)

Streszczenie. Praca obrazuje zależności zachodzące pomiędzy wiekiem drzew, pozycją biosocjalną a miąższością i udziałem drewna młodocianego, dojrzewającego i dojrzałego. Obiektem badań były drzewostany świerkowe reprezentujące II, III oraz IV klasę wieku, wyrosłe w warunkach lasu mieszanego górskiego. Strefy drewna młodocianego, dojrzewającego oraz dojrzałego zostały wyznaczone na podstawie stosunku szerokości strefy drewna późnego do wczesnego w przyrostach rocznych. Drewno tworzone w ulistnionych łodygach i w bliskości aparatu asymilacyjnego wykazuje odmienną strukturę i charakter od drewna powstającego w częściach od niego oddalonych. Z tego względu wyróżniamy drewno młodociane oraz dojrzałe. Najogólniej mówiąc, drewno młodociane jest nierozerwalnie związane z silnym wpływem aparatu asymilacyjnego, czyli z ugałęzioną częścią drzew. Drewno młodociane występuje w każdym drzewie i jest z punktu praktycznego wykorzystania drewna elementem niepożądanym, ograniczającym możliwości wykorzystania surowca drzewnego.

Słowa kluczowe: drewno młodociane, drewno dojrzewające (przejściowe), drewno dojrzałe, świerk pospolity

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